ASD/ENA-TR-80-

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AD A108376

MIL-STD-462-APPLICATION NOTE

IDENTIFICATION OF BROADBAND AND NARROWBAND EMISSIONS

1 May 1980

Aeronautical Systems Division
Deputy for Engineering
Directorate of Avionics Engineering
Mission Avionics Division
Electromagnetic and Interference Compatibility Branch
Wright-Patterson Air Force Base, Ohio

"OPSEC HAS BEEN CONSIDERED IN ACCORDANCE WITH AFR 55-30/AFSC SUP 1."

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1. INTRODUCTION

One of the most troublesome areas in electromagnetic interference testing per MIL-STD-461, MIL-STD-462, and MIL-STD-463 is the classification of measured interference emissions as either narrowband or broadband. MIL-STD-462 provides criteria for making this determination, however, MIL-STD-462 is often ignored or the intent of MIL-STD-462 is misunderstood such that there is little continuity in classification techniques used by various test agencies. The purpose of this application note is to provide clarification on this subject by discussing the technical basis behind the MIL-STD-462 technique, concepts involving narrowband noise, and optimum bandwidth selection.

2. BACKGROUND

a. In the most strict sense, an unmodulated sine wave at some frequency is a pure narrowband signal which occupies an infinitesimally small portion of the frequency spectrum (Figure 1). A receiver with adequate sensitivity tuned to this signal will detect the signal at a constant amplitude independent of the receiver's bandwidth. Units of signal amplitude are in terms of measured voltage (normally dBuV). On the other extreme, a single impulse in the time domain of infinite amplitude and essentially zero time duration is a pure broadband signal which will produce a uniform and continuous density across the frequency spectrum (Figure 2). With adequate receiver sensitivity the detected signal level at the receiver output is completely independent of tuned frequency and is directly proportional to the impulse bandwidth of the receiver. Units of signal amplitude are normalized in terms of voltage per bandwidth (normally dBuV/MHz).

b. The sensitivity of a receiver is the minimum input signal for which a specified change in the output of the receiver will result(signal to noise ratio). Both the narrowband and the broadband sensitivity of a receiver is dependent upon selected bandwidth. The background level of a receiver is composed of random noise which has spectral components resulting from many independent events which are random in nature without any specific phase relationship. Due to this reason random noise results in a detected power in the receiver which is proportional to bandwidth. Since the associated voltage is proportional to the square root of the power, the detected voltage is also proportional to the square root of the bandwidth. As the receiver bandwidth is increased, the receiver detected voltage due to background noise rises thus impairing the ability to detect pure narrowband signals close to the internal noise level (decreased narrowband sensitivity). Conversely, smaller bandwidths provide improved narrowband sensitivity. Figure 3 shows plots of a constant level sine wave input signal together with receiver background noise for two different bandwidths.

c. Broadband sensitivity changes in direct opposition to narrowband sensitivity. As noted earlier, an ideal impulse signal produces a density in the frequency spectrum such that the detected voltage in the receiver is directly proportional to bandwidth. This relationship exists because the spectral content of an impulse signal is phase coherent since it results entirely from a single discrete event. Since the detected voltage due to random noise is proportional to the square root of bandwidth as compared to impulsive noise which is directly proportional to bandwidth, larger bandwidths provide improved sensitivity to pure impulsive signals. Conversely, smaller bandwidths provide poorer impulse sensitivity. Figure 4 shows plots of a constant impulse generator input for two different bandwidths together with separate scans displaying receiver background noise. Thus, changing receiver bandwidth to improve sensitivity for one classification of noise causes the receiver to become less sensitive to the second classification of noise.

d. Unfortunately, typical noise signatures of electronic equipments very seldom exhibit characteristics of classical narrowband or broadband noise. Noise in any portion of the frequency spectrum is often composed of contributions from several different sources. Plots of amplitude versus frequency for different receiver bandwidths produce results which do not agree with those expected due to an ideal impulse or sine wave noise. A signal which already has narrowband characteristics (sharply tunable) in one bandwidth will often exhibit a significantly lower amplitude in a smaller bandwidth due to greater resolution of the spectral content. Signals which appear to be impulsive may not produce detected voltage proportional to bandwidth as anticipated due to random noise or sine wave contributions. Noise which appears to have a relatively flat impulsive spectrum with one bandwidth may be resolved into discrete spectral lines with a smaller bandwidth. Figure 5 shows the effects of changing bandwidths for a 12 kHz square wave input to a receiver. An interesting example of this last effect is the type of noise produced by impulse generators used for calibration. Impulse generators produce a train of very short pulses at a specified rate (see paragraph 4.96 of MIL-STD-463A). Since the generated signal is periodic, a Fourier analysis of the spectral content will result in a very large number of discrete spectral lines (pure narrowband) directly related to the pulse rate. The amplitude of the spectral lines will be essentially constant up to very high frequencies due to the very short pulse duration. For most receiver bandwidths the detected signal will appear to be impulsive since many spectral lines will be within the receiver bandpass for any tuned frequency. However, for bandwidths which are small compared to the pulse rate of the generator, the receiver will resolve the signal into its individual spectral lines. With the selection of an excessively small receiver bandwidth, one could argue that an impulse generator is a narrowband signal generator.

3. MIL-STD-461/462/463

a. MIL-STD-461, MIL-STD-462, and MIL-STD-463 are, as the titles state, Military Standards. The documents standardize requirements, test techniques, and definitions so that consistent results will be obtained regardless of test agency. Paragraph 4.2.6 of MIL-STD-462 provides the criteria for distinguishing between narrowband and broadband noise. Two criteria are included. The first criteria is based on tunability of the noise and is directly applicable to automatic plotting. The receiver is tuned plus and minus two impulse bandwidths about a selected frequency and the decision is based on the amplitude variation of the selected signal. If a signal tunes sharply, it is considered to be narrowband for the selected bandwidth. Otherwise, it is broadband. The second criteria requires a measurement of the pulse repetition rate of the signal. If the impulse bandwidth of the receiver is less than the pulse repetition rate, the signal is narrowband. Otherwise, the signal is broadband. This criteria addresses the concept discussed earlier for the impulse generator that any periodic pulsed signal will produce discrete spectral components related to the pulse repetition rate. The criteria recognizes the fact that for pulse rates less than the impulse bandwidth of the receiver, the signal can never be detuned since at least one spectral line will always be within the receiver passband. Pulse CW (continuous wave) is treated independently by paragraph 4.2.6.1 of MIL-STD-462 as a narrowband signal.

b. Test techniques used by some test agencies are not in accordance with the above criteria.

(1) MIL-STD-462 does not specify the use of more than one bandwidth in any frequency range. The intent of MIL-STD-462 is that one bandwidth is selected and that noise is classified strictly on how the noise appears with regard to that bandwidth. The use of two different bandwidths with noise in a wide bandwidth being called broadband and noise in a small bandwidth being called narrowband is not in accordance with MIL-STD-462. This technique certainly does not clarify or simplify the noise classification problem. Most test agencies using this technique generally attempt to classify the noise in each of the bandwidths as being either narrowband or broadband and then ignore the portions of the plot for which the noise classification does not agree with the type of bandwidth selected. The objection to this technique is that the use of unrealistically small or large bandwidths for evaluating noise have the effect of making the MIL-STD-461 limits easier to meet. Noise which is not a pure sine wave but which would be classified as narrowband in a particular bandwidth will be more greatly resolved in a smaller bandwidth. This greater resolution always results in a lower amplitude for the measured levels. Since the MIL-STD-461 narrowband limit is independent of bandwidth, the equipment under test is more likely to be within limits. Therefore, the use of smaller and smaller bandwidths would definitely be to the advantage of the equipment manufacturer. A similar effect exists for broadband noise evaluation. As bandwidth is increased, the allowable detected voltage in the reciever which corresponds to the MIL-STD-461 broadband limit rises proportionally. The difference in detected voltage due to

an ideal impulse signal and the allowable detected level will remain constant independent of bandwidth. However, other types of noise which are not truly impulsive at the frequency of interest will produce detected voltages which are less than proportional to bandwidth resulting in the MIL-STD-461 limit being easier to meet. In the case of broadband measurements, it would be to the equipment manufacturer's advantage to use wider and wider bandwidths to measure broadband noise. Therefore, the use of two bandwidths for measurements (wide bandwidths for broadband and small bandwidths for narrowband) inherently permits manipulation of detected levels with regard to acceptance limits.

(2) Another practice used by some test agencies which is not in accordance with MIL-STD-462 is to significantly increase the hold time of the peak detector during independent broadband plots to smooth out excursions in the plotted data. Paragraph 50.0 of MIL-STD-462 (Appendix A) specifically requires that characteristics of the peak detector be such that signals can be resolved to one percent of the plot. The use of long hold times misrepresents the data since the plotted information is no longer related to bandwidth characteristics of the receiver thus defeating the tunability classification criteria.

(3) Paragraphs 40.0 and 50.0 of MIL-STD-462 (Appendix A) require that a peak detector be used for all measurements. The use of carrier or field intensity detectors is not permitted. Some test agencies compare noise levels resulting from the peak and carrier detectors in determining noise classification. Not only does this technique violate the concept of standardization, but it also presents additional difficulties. Carrier detectors have a slow response time and require long automatic scan times for certain combinations of bandwidth and frequency range so that the detector can charge to its full value. Normally used scan times of one minute per octave band can give misleading results for other than peak detectors. Figure 6 shows plots of a pure sine wave for peak and carrier detectors using a one minute scan time. Although the carrier detector level should be identical to the peak detector level, there is a 20 dB discrepancy. Carrier detectors also give misleading results for signals which have high peak power levels but low average power levels such as pulsed CW. The peak detector will charge to the true peak of the signal, while the carrier detector will average the on and off times of the signal and indicate a much lower level. Figure 7 demonstrates this effect for a signal at 78 MHz with a pulse modulation of 10 μsec pulse width and 4.5 kHz repetition rate. The scan time of the receiver has been slowed down for the carrier detector to 5.5 minutes to allow the detector to charge to its full value. There is a 38 dB discrepancy. Thus, the carrier detector makes this narrowband signal appear to be broadband.

4. <u>BANDWIDTH SELECTION</u>

a. The use of a single carefully selected bandwidth for any particular frequency range is consistent with the primary reason for performing emission testing and use of automatic measurement equipment as required by MIL-STD-462. From an aircraft systems viewpoint, the overwhelming concern is to prevent degradation of aircraft receivers due to emitted noise from subsystems. Therefore it is important to know what the noise emitted from a system looks like with regard to realistic receiver bandwidths. As an example, communication receivers on aircraft have bandwidths typically on the order of 20 kHz. Therefore, two sets of test data showing narrowband results using a 100 Hz bandwidth together with broadband results using a 1.0 MHz bandwidth are not nearly as meaningful as one set of data showing the noise signature with a bandwidth in the vicinity of 20 kHz.

b. MIL-STD-461 and MIL-STD-462 do not directly specify bandwidths which must be used. Ideally, the documents could ignore the narrowband/broadband issue by simply allowing a maximum acceptable detected voltage using a specified bandwidth for a particular frequency range regardless of the type of noise which caused the detected voltage. This approach is difficult to implement due to the variety of instruments available for use which do not have common bandwidths. However, the concept can be applied by comparing the broadband and narrowband limits of MIL-STD-461. There is an implied bandwidth relationship between the two limits for a particular test method. Test receiver bandwidths can be chosen such that a broadband signal at the broadband limit at some frequency will develop the same voltage in the receiver bandpass as a narrowband signal at the narrowband limit. This optimum bandwidth selection removes the argument of whether a signal is broadband or narrowband since if one limit is exceeded the second limit is also exceeded. These bandwidth relationships are plotted in Figure 8 for Test Methods CE03, CE04, and RE02 for MIL-STD-461A, Notice 3, Class A equipment limits. The bandwidth values for the curves were obtained by means of the following equation:

$$\text{Bandwidth (kHz)} = 1000 \times \text{Antilog}_{10} \{(\text{NB Limit} - \text{BB Limit})/20\}$$

Similar bandwidth calculations must be made for alternate sets of limits for other than class A equipment or for limits tailored for a specific piece of equipment.

c. In actual practice, bandwidths cannot be continuously varied to follow the curves in Figure 8. However, sufficient bandwidth capability is provided on most receivers used for testing such that a bandwidth close to the curve can be selected for each receiver frequency band. Figures 9 and 10 show examples of placement of Class A limits for CE03/CE04 and RE02 respectively on graphs for one instrumentation series. These limits are for the passive transducers (no preamplifiers) listed on the graphs. For alternate transducers the difference between the two limits will remain constant, however, varying amounts of attenuation will be required to place the limits appropriately on the plot. The background noise level of the receiver has been plotted for the selected bandwidths and the required attenuator settings for the listed transducers.

5. CONCLUSIONS

Noise classification techniques used by many test agencies are not in accordance with MIL-STD-462 requirements. The intent of MIL-STD-462 is that one bandwidth be used in each receiver frequency band with the noise being classified as it appears with regard to that bandwidth. One of the main difficulties is selecting appropriate receiver bandwidths. An approach to bandwidth selection ~~has been~~ presented which is consistent with noise classification in accordance with MIL-STD-462 and which eliminates some of the difficulty in determining the appropriate classification of noise.

REFERENCES:

a. MIL-STD-461A, Notice 3, Electromagnetic Interference Characteristics, Requirements for Equipment, 1 May 1970.

b. MIL-STD-462, Notice 2, Electromagnetic Interference Characteristics, Measurement of, 1 May 1970.

c. MIL-STD-463A, Definitions and Systems of Units, Electromagnetic Interference and Electromagnetic Compatibility Technology, 1 June 1977.

d. Hewlett Packard, Spectrum Analysis...Noise Measurements, Spectrum Analysis Series, Application Note 150-4, Chapters 1 and 2, April 1974.

e. AFSC Design Handbook 1-4, Electromagnetic Compatibility, Design Note 6B2.

Any comments or questions concerning this application note should be addressed to: ASD/ENAMA (Mr. John C. Zentner), Wright-Patterson AFB, Ohio 45433. Telephone: 1-513-255-2907/5986.

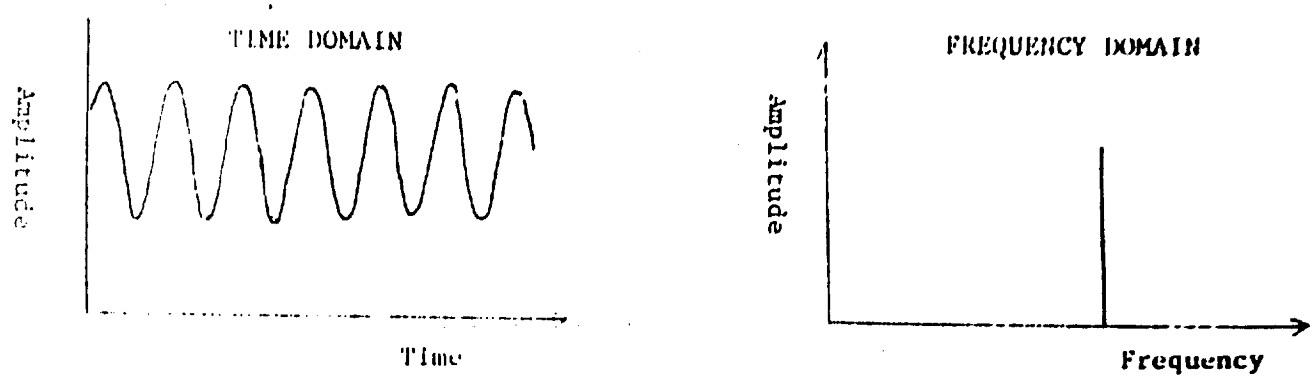


FIGURE 1. PURE UNMODULATED SINE WAVE

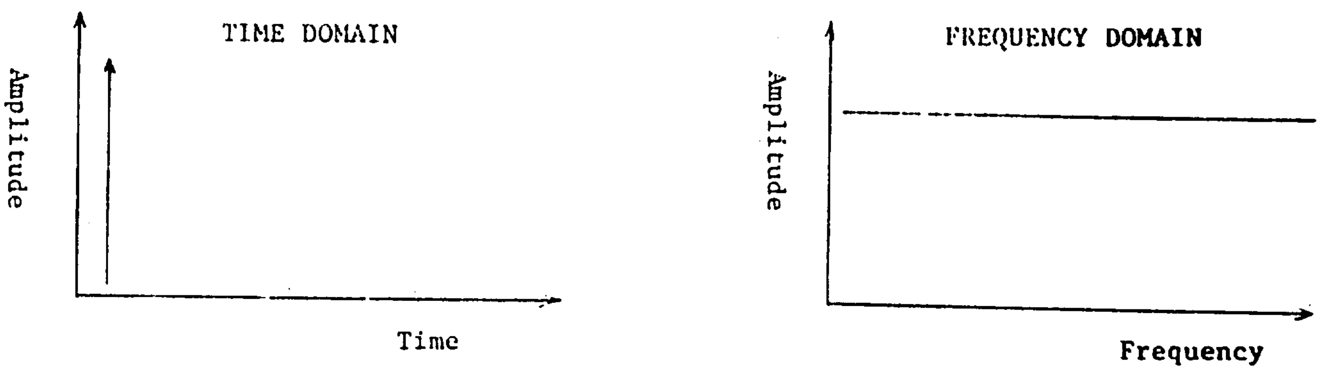


FIGURE 2. IDEAL IMPULSE

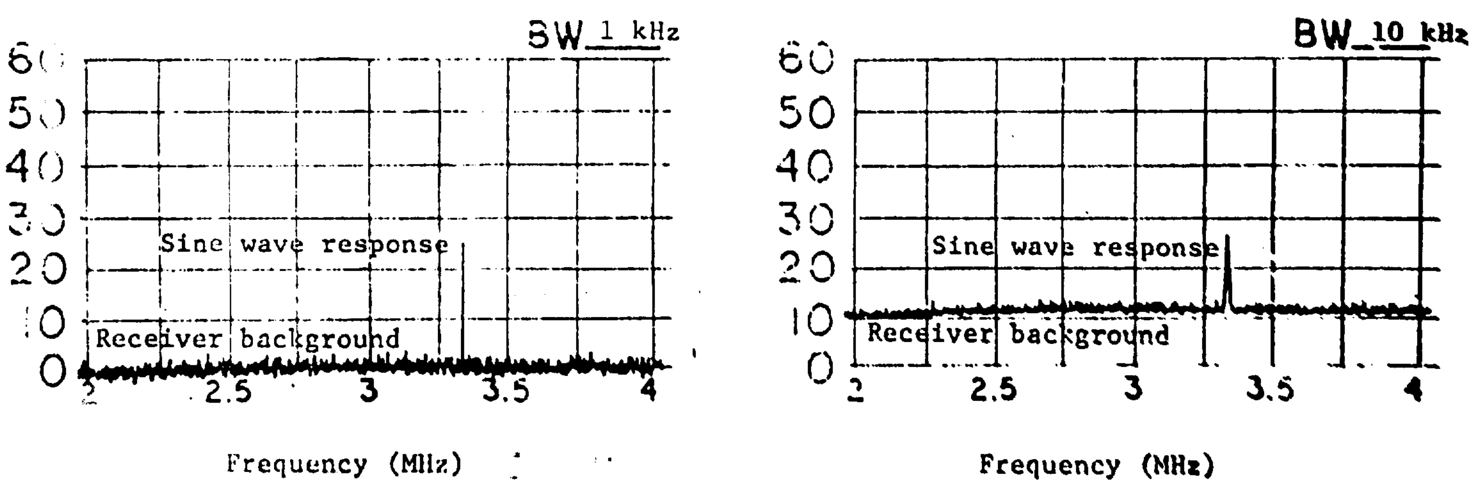


FIGURE 3. NARROWBAND SENSITIVITY FOR DIFFERENT BANDWIDTHS

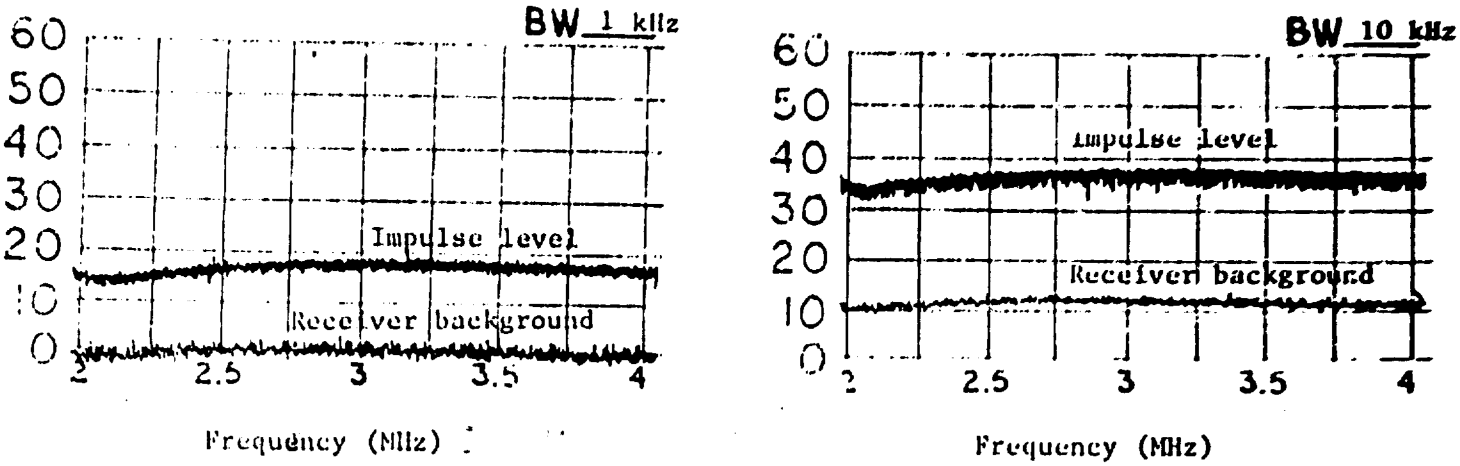


FIGURE 4. BROADBAND SENSITIVITY FOR DIFFERENT BANDWIDTHS

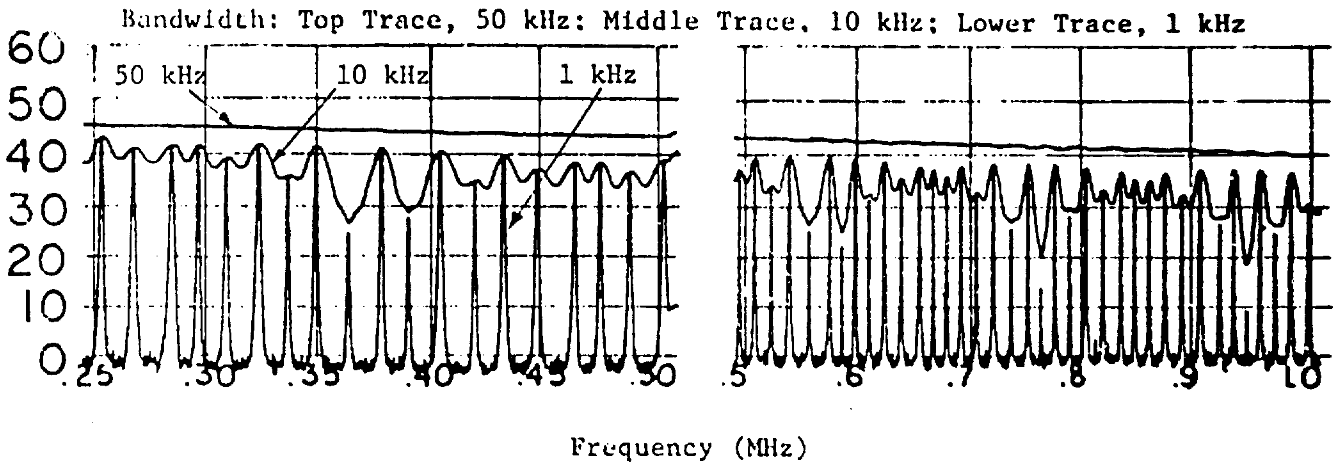


FIGURE 5. VARIATION IN APPEARANCE OF NOISE WITH CHANGE OF BANDWIDTH

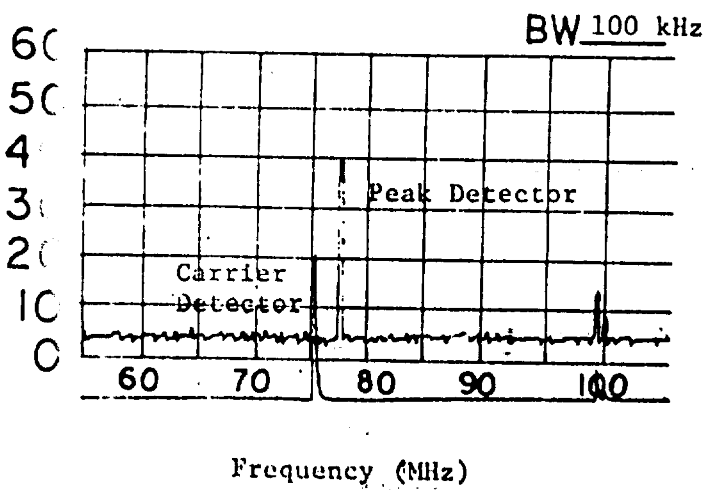


FIGURE 6. DETECTOR RESPONSE TO SINE WAVE

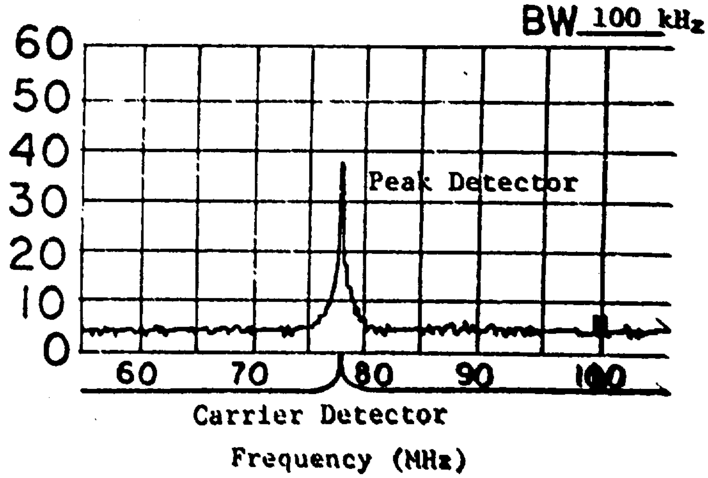


FIGURE 7. DETECTOR RESPONSE TO PULSED CW

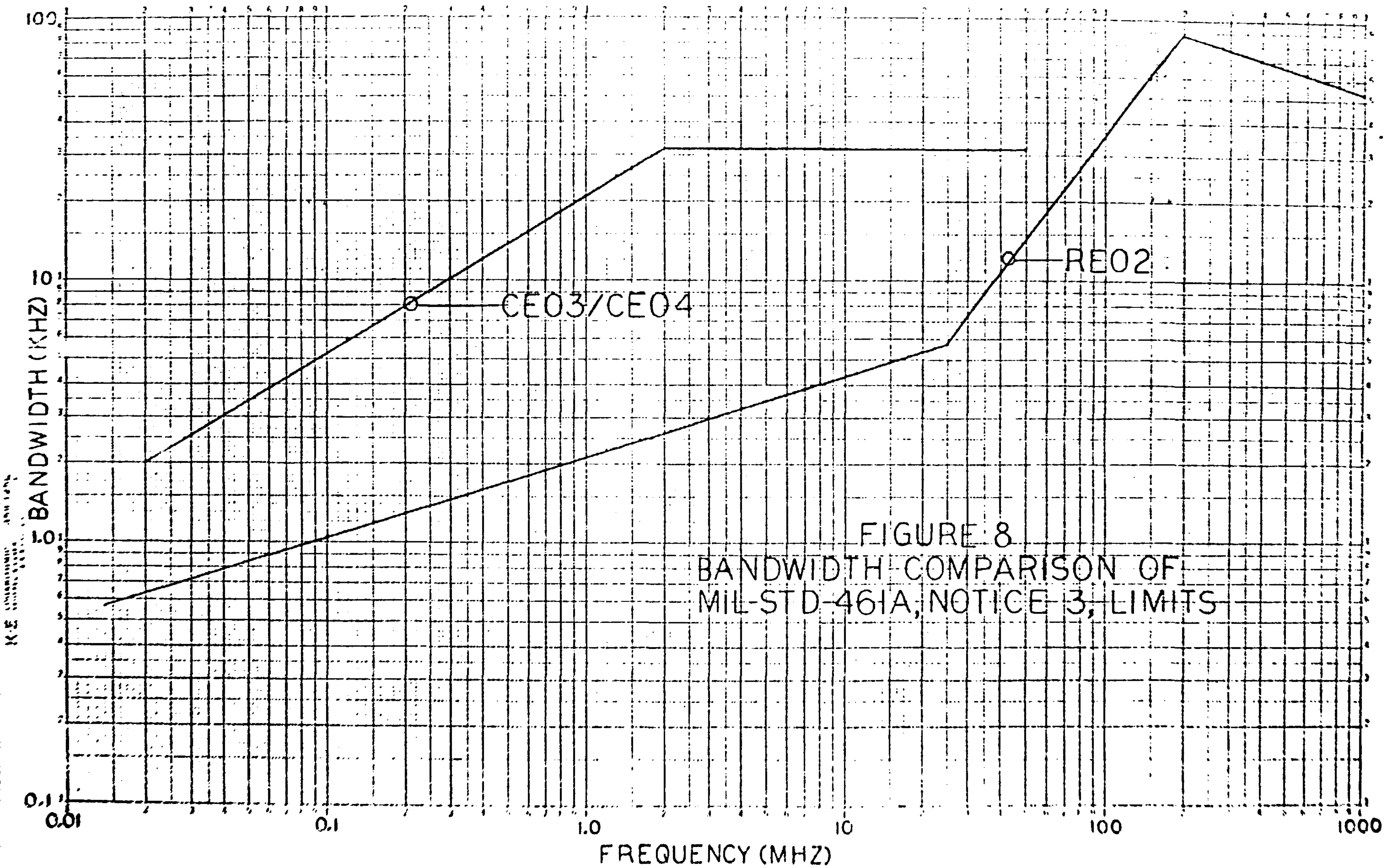


FIGURE 8
BANDWIDTH COMPARISON OF
MIL-STD-461A, NOTICE 3, LIMITS

FIGURE 9

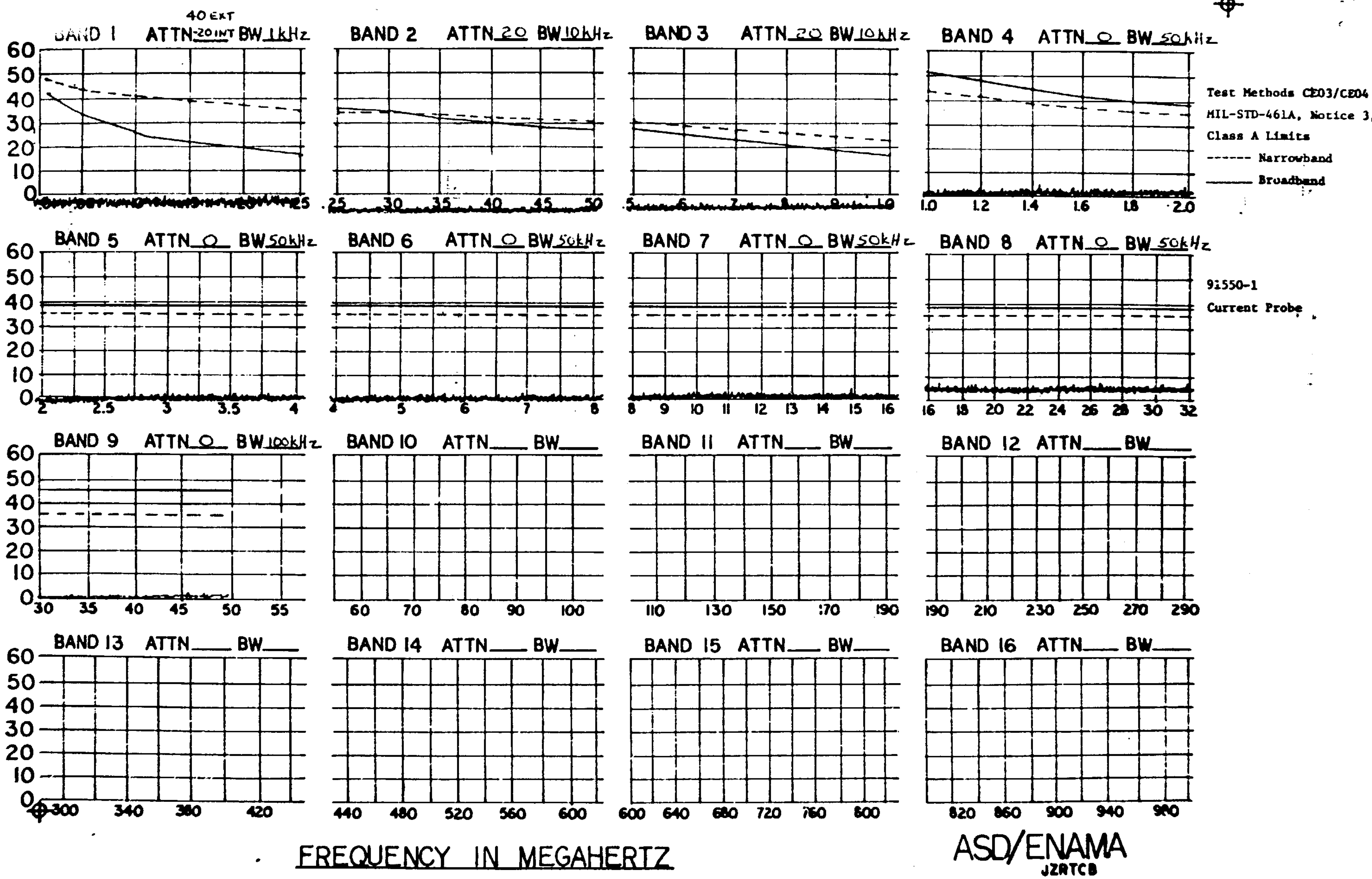
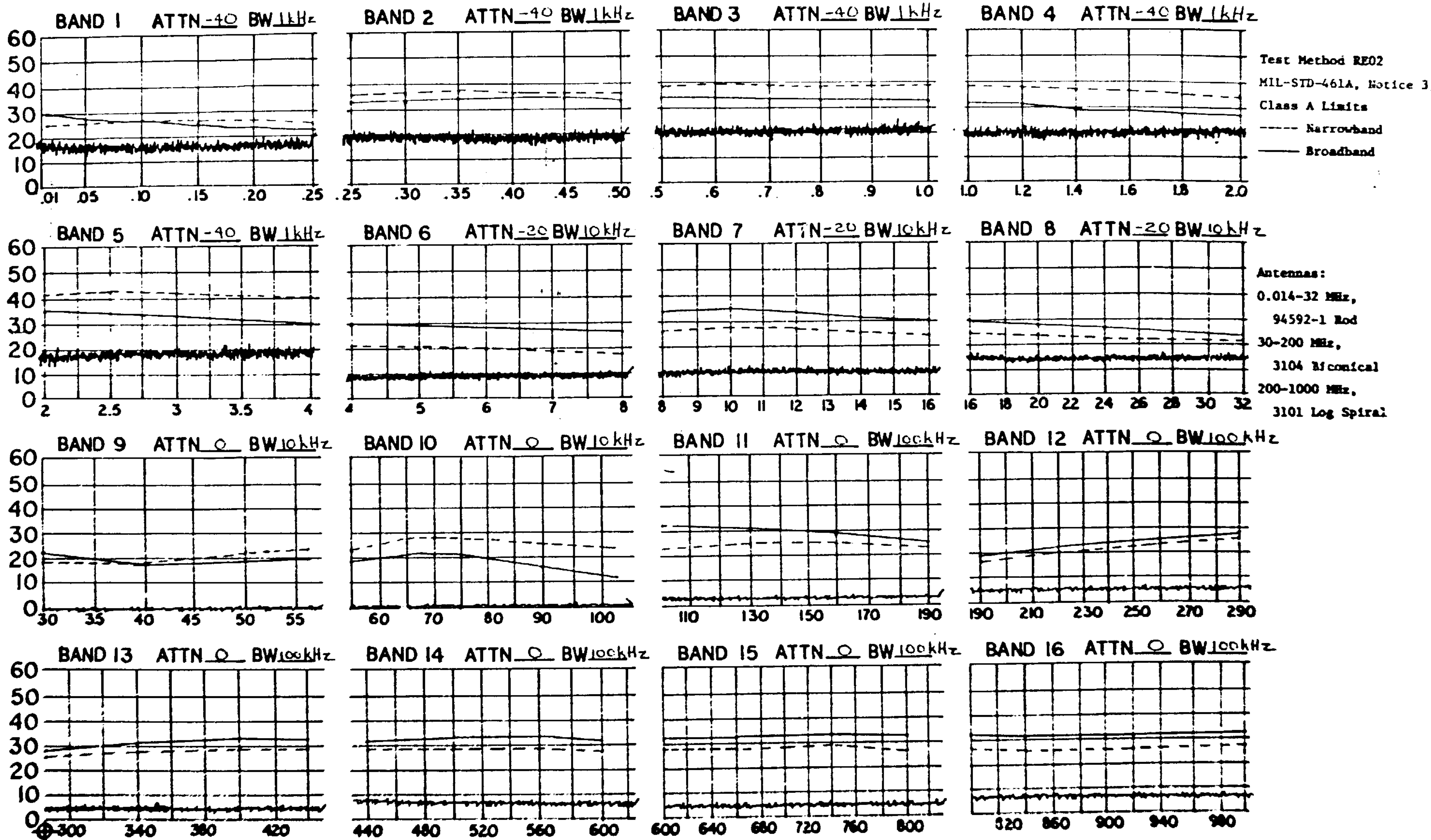

BAND 1 ATTN 20 INT 40 EXT BW 1 kHz
BAND 2 ATTN 20 BW 10 kHz
BAND 3 ATTN 20 BW 10 kHz
BAND 4 ATTN 0 BW 50 kHz
BAND 5 ATTN 0 BW 50 kHz
BAND 6 ATTN 0 BW 50 kHz
BAND 7 ATTN 0 BW 50 kHz
BAND 8 ATTN 0 BW 50 kHz
BAND 9 ATTN 0 BW 100 kHz
BAND 10 ATTN BW
BAND 11 ATTN BW
BAND 12 ATTN BW
BAND 13 ATTN BW
BAND 14 ATTN BW
BAND 15 ATTN BW
BAND 16 ATTN BW
Test Methods CE03/CE04
MIL-STD-461A, Notice 3,
Class A Limits
------ Narrowband
——— Broadband
91550-1
Current Probe
FREQUENCY IN MEGAHERTZ
ASD/ENAMA
JZRTCB

FIGURE 1



FREQUENCY IN MEGAHERTZ

ASD/ENAMA
JZRTCB